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The investigation of tribological characteristics of surface improved by magnetic polishing and roller burnishing

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Abstract

In this paper the author presents the results of his research. During the research the fine turned and then grinded pre-machined surfaces were polished and roller burnished in the magnetic field as to examine the possibility of the combination of both technologies. The aim was to improve the tribological parameters of treated surface. C45 normalized steel was used as workpiece material which was machined with different technological parameters. The evaluation was completed by advanced measuring and IT equipment.

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Keywords: magnetism, burnishing, polishing, finishing, economic, hand scraping

1. Introduction

Denomination Magnetism Aided Machining (MAM) comprises a number of relatively new industrial machining processes (mainly finishing and surface improving) developed presently, too. MAM is effective – among others – for polishing, deburring and burnishing of cylindrical and flat (in some cases even 3D surfaces) metal parts. The magnetic force makes these processes simpler and more productive. Machining force is generated by an adjustable electromagnetic field between two magnetic poles within the working area ensuring the necessary pressure and speed difference between the tools (abrasive grains, pellets or rollers) and the workpiece.

2. MAM technologies

2.1. Magnetic Abrasive Polishing (MAP) [1]

Polishing as finishing operation is one of the most important final machining process. Polishing for decrease of surface roughness and increase of resistance against wear, corrosion and mechanical loadings.

Magnetic abrasives are emerging as important finishing methods for metals. Magnetic Abrasive Polishing is one such unconventional finishing process developed recently to produce efficiently and economically good quality finish on the internal and external surfaces of tubes as well as flat surfaces made of magnetic or non-magnetic materials. In this process, usually ferromagnetic particles are used sintered with fine abrasive particles (Al_2O_3, SiC, CBN or diamond), furthermore homogeneously mixed loose ferromagnetic and abrasive particles are also used in certain applications.

Since the magnitude of machining force caused by the magnetic field is low but controllable, a mirror like surface finish (R_a value in the range of nano-meter) is obtained. In MAP, mirror finishing is realized and burrs are removed without lowering the

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accuracy of the shape. This fine finishing technology using magnetic abrasives have a wide range of applications. The surface finishing, deburring and precision rounding of the workpiece can be done simultaneously.

The MAP equipment for cylindrical surfaces was adapted to a universal engine lathe (Fig. 1.).

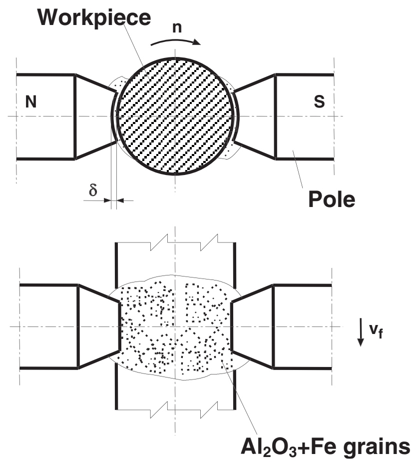

Fig. 1. Figure of MAP[1]

2.2. Magnetic Assisted Roller Burnishing (MARB)

The main goal of roller burnishing is to achieve high-quality smooth surfaces or surfaces with pre-defined surface finish. One or more balls plastify and deform the workpiece's surface layer. This process is used when the goal is to either achieve a high-quality surface finish or when a pre-defined surface finish cannot be achieved by machining. [2]

At the contact point, the burnishing force generates contact stresses in the material's edge zone. If this stress is higher than the material's yield strength, the material near the surface starts to flow. As the ball moves across the workpiece surface, the surface's peaks are pressed down, almost vertically, into the surface and the material then flows into the valleys between the peaks (Fig. 2.). [3]

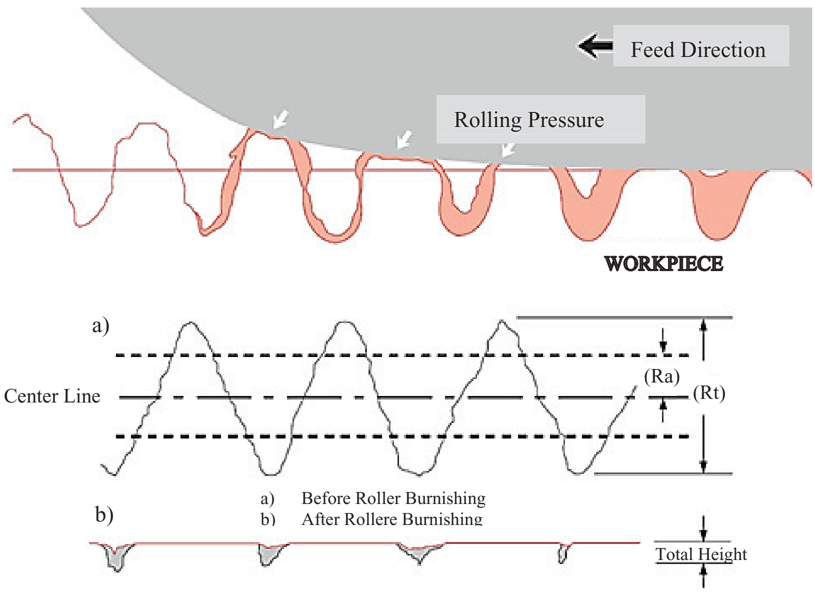

Fig. 2. Evolution of surface by roller burnishing [3]

The resulting smooth surface occurs not because the peaks are bent into the surface, but because the material at the workpiece surface is plastically deformed and the material flows, eliminating surface roughness. [3]

Almost all processes for the manufacturing of high-quality surfaces can be replaced by roller burnishing (e.g. fine turning, grinding, superfinishing, lapgrinding). This proven process entails considerable technological and economic advantages for surfaces in the roughness area R_z <10 µm.

For roller burnishing mechanical force was applied to press the rolling ball onto the surfaces. To avoid the harmful deformation by mechanic pressing, the necessary pressure and relative speed between the tools and the workpiece are ensured by the magnetic force. This is the Magnetic Assisted Roller Burnishing (MARB) process. [2]

The magnetic roller burnishing equipment for cylindrical surfaces was adapted to a universal engine lathe (Fig. 3.)

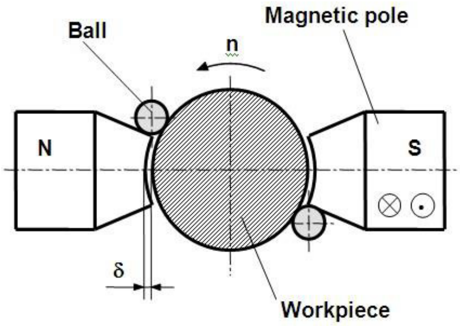

Fig. 3. Figure of MARB technology[1]

As you see, this equipment is similar to the previously showed equipment of MAP technology, but in this case, instead of the abrasive grains two hard bearing balls were applied as rolling tools.

3. Experimental conditions

3.1. Procedure of the experiment

Many experiments have been carried with these technologies, where the effect of changes of the technological parameters and conditions was examined on the workpieces.

In this paper, the aim was to make a comparison between the combined use of the two technologies. This means there were two fine turned and grinded shaft (number 1 and 2). Both were separated into nine equal sections. One of them was polished with nine different technological parameters and the other was roller burnished with similarly varying technological parameters. Then the machined surfaces were measured by roughness tester (type of MITUTOYO Formtracer SV-C3000) and then the best polished and rolled surface has been chosen by the measured results. In the next step, the polishing and rolling are carried out again but now the rolled cylinder is polished with the technological parameter of the best polished surface (Fig. 4. a) and the polished cylinder is also roller burnished with the same method (Fig. 4. b). Then the surfaces were measured with the roughness tester and those results were evaluated.

a) b)

Fig. 4. (a) Polishing of the rolled surfaces and (b) roller burnishing of the polished surfaces

3.1. Technological parameters

The electromagnetic poles were fixed onto the slide of the lathe. In the tests the voltage (U = 40 V), current (I = 10 A) (direct current, adjustable) and the generating magnetic induction (B = 0,96 T) were the same under rolling and polishing too. The generated magnetic induction was reduced (B = 0,75 T) with polishing grain, because of the applied Al_2O_3 shielding properties. During processing the workpieces (C45-type steel rods of 27,5 mm diameter and 400 mm length) were setup between centres.

The magnetic jaws (poles) were surrounded the workpiece with a δ = 3 mm gap (clearance). Prior to the process, the workpieces were fine turned and grinded to $R_a \sim 1$ µm surface roughness.

Both technologies operate similar principles, but two technologies were used. Depending on this, when polishing the polishing time (T_p) and polishing speed (v_p) were changed, while roller burnishing changed the rolling speed (v_r) and feed (f_r). When defining the technological parameters I used in earlier parameters of tests and those characteristic of the technology. The results are presented in the two table below (Table 1. and Table 2.)

Table 1. Technological parameters of polishing.

Surface number	v_p (m/min)	T (min)
1P	23	
2P	65	1
3P	92	
4P	23	
5P	65	2
6P	92	
7P	23	
8P	65	0,5
9P	92	

Table 2. Technological parameters of roller burnishing.

Surface number	v_r (m/min)	f_r (mm/rev)
1R	23	
2R	32	0,05
3R	65	
4R	23	
5R	32	0,1
6R	65	
7R	23	
8R	32	0,2
9R	65	

4. Evaluation

The measured R_a values can be found in Fig. 5. Next to the name of the different types of machined in parentheses there is the number of shafts.

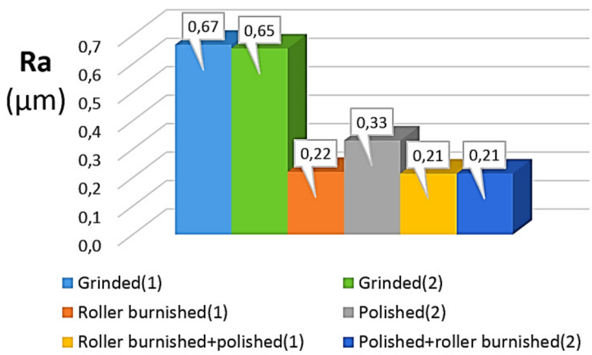

Fig. 5. The R_a values of different MAM technologies

The resulting roughness values were in line with expectations. Although the values of roughness of sliding surfaces have a major influence of the movement on each other, the R_a value does not feature the sliding surfaces (e.g. sliding line or bad) behavior during operation. For this reason, the tribological characteristics are drawn into the attention.

To determine these properties the R_{sk} (skewness) and R_{ku} (kurtosis) parameters are suitable. In the followings, the way of the polishing and roller burnishing affected the R_{sk} and R_{ku} parameters is investigated.

4.1. The R_{sk} and R_{ku} profile

The skewness (R_{sk}) is a measure of the symmetry of the profile about the mean line, giving information on asymmetrical profiles for surfaces with the same values of R_a and R_{ms}. Negative values of Rsk indicate a predominance of troughs, while positive ones are observed for surfaces with peaks (Fig. 6.). [4]

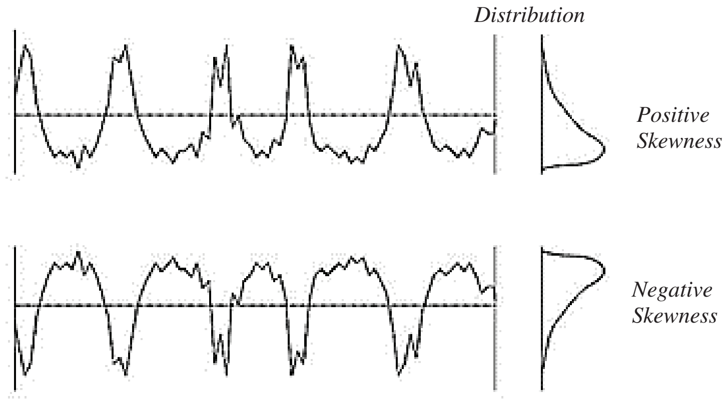

Fig. 6. The profile type of R_{sk} [4]

The kurtosis (R_{ku}) is a measure of the sharpness of the profile about the mean line that provides information on the distribution of spikes above and below the mean line. Thus, spiky surfaces will have a high kurtosis value ($R_{ku} > 3$) and bumpy surfaces a low value ($R_{ku} < 3$) (Fig. 7.). [4]

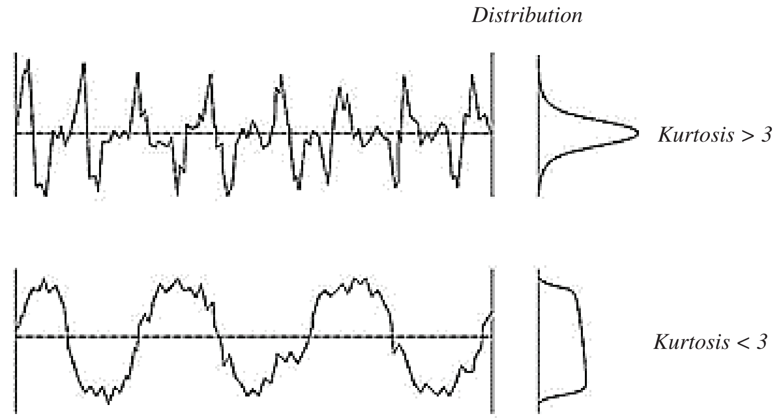

Fig. 7. The profile type of R_{ku} [4]

4.2. Trend of R_{sk} and R_{ku} parameters

The statistical index numbers of machined surface roughness are defined by the so-called topological map (Fig. 8.). On the topological map the R_{sk} and R_{ku} values of the surfaces made with different manufacturing technologies can be seen and these technologies create group in the map. [5]

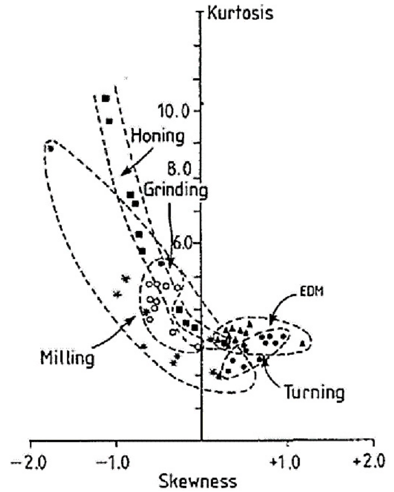

Fig. 8. R_{sk} and R_{ku} topological map of surfaces made with different manufacturing technologies [6]

The difference between these groups explains why surfaces made with different technologies behave differently during operation. The aim was to place the groups of MAM technologies on the topological map.

The tribological behavior of technological surfaces are related to the micro-geometry of surfaces. It was observed that surfaces with better wear resistance had negative R_{sk} and high R_{ku} values. The friction was the smallest in those places where R_{sk} was the lowest and the value of R_{ku} was the highest. [4]

4.3. The R_{sk} and R_{ku} topological map of MAM technologies

Fig. 9. shows the topological map of MAM technologies where it is apparent that the values of certain technologies are dispersion or converging.

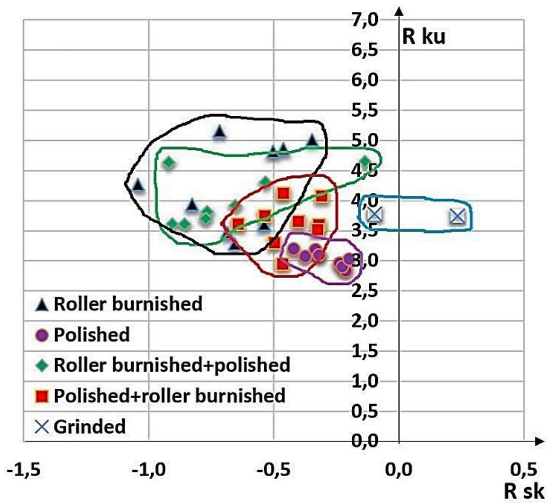

Fig. 9. Topological map of MAM technologies

The difference between Fig. 8. and Fig. 9. of MAM technologies belong to the fine-machining group is notable, especially in case of polished surfaces. As it was stated, in case of working surfaces the surface roughness (e.g. R_a or R_z) is also important. So the tribological aspect for the Fig. 9. the polished and roller burnished surfaces (marked with red color) have been regarded the best result.

5. Conclusion

Based on the results of the experiments regarding magnetic abrasive polishing, roller burnishing and combination of both, it has been proved that these processes can be effectively and economically used for finish machining the cylindrical surfaces of metal workpieces. The magnetic field speeds up the finishing processes, makes them cost-effective and environment-friendly. It was proven that surface quality and process productivity can be easily affected by adjusting the various magnetic and kinematical parameters of the process.

In addition, effective results can be achieved with MAM technologies from tribological point of view. Therefore my future personal aim is to optimize the technological parameters and the application of MAM technologies at the same time to reduce the machining time and cost.

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